Managing Postharvest Diseases of Apple and Pear in the Orchard and Storage
Postharvest Diseases of Tree Fruit

- More than 90 fungal species

- Blue Mold
- Gray Mold
- Bull’s Eye Rot
- Speck Rot
- Sphaeropsis
- Yellow Rot
- Mucor Rot

Trade issue complex disease
Blue Mold

Penicillium expansum
Penicillium sp.

- Typically postharvest
- Wound pathogen
- Soft and watery
- Profuse sporulation
- Sanitation: Rooms and bins
- Use of fungicides (conventional) postharvest

**Economic impact:** ~$5 million
Gray Mold

*Botrytis cinerea*

- Pre and postharvest (nesting)
- Latent infections
- Field sanitation: **Key**
- Conventional: use of fungicides pre- and postharvest
- High risk for resistance development
Bull’s Eye Rot

Neofabraea perennans (WA)
N. Alba (OR),
N. malicorticis,
Cyptosporiopsis kienholzii

- Pre-harvest infections
- Cankers
- Latent infections (>4 months of storage)
- Wet pre-harvest conditions
- Orchard sanitation
- Quarantine: export problems (some species)
Speck Rot

Phaciopicnys washingtonensis (Spek rot-Apple)
Phacidiopycnis piri (pear)

- Pre-harvest infections
- Crab apple pollinizers: source of inoculum
- Latent infections
- Weak/slow pathogen
- 15-25% of total decay (2005)
- Quarantine: Trade problems
- Orchard sanitation: key in organic/conventional
Yellow Rot

*Lambertella corni-marris*

- Wound pathogen
- Preharvest infections?
- Inoculum source: unknown yet
- Latent infections
- First reported in 2015: 3-5% of total decay
- Quarantine: export problems
- Conventional: Scholar and Penbotec effective
Postharvest Diseases

Occurrence in WA 2016

- Blue mold: 34%
- Gray mold: 10%
- Mucor: 17%
- Bull's eye rot: 6%
- Phacidiopycnis: 4%
- Neonectria: 3%
- Others/Disorders: 20%

Incidence (%)
Postharvest Diseases

Epidemiology and infection timing

Spring
- Bloom
  - Botrytis?
  - Gray mold

Summer
- Mid-late
  - Botrytis? Gray mold
  - Neofabraea: Bull’s
  - Phacidiopycnis
  - Sphaeropsis

Postharvest
- Harvest/Postharvest
  - Penicillium: Blue mold
  - Mucor piriformis:
    - Mucor rot

Infection stage way vary with inoculum availability and weather conditions
Postharvest Diseases

Orchard selection

- **Site Selection (new orchards)**
  - Sunny, well-aerated,
  - Mid-high and well drained soil types
  - Isolating large lots of trees (~1/2 mile):
    Hedges, neglected neighboring tree fruit.

- **Planting**
  - **Density**: 800 to 1000 trees/ac, more spaced trees may have less diseases
  - **Rootstocks**: Resistance known for fire blight & Phytophthora but not for storage rots
  - **Certified** disease free plant material
  - **Weed** management: important for young trees
  - Avoid areas with history of **replant disease**
Postharvest Diseases

Host Management

- Cultivar Selection (new orchards)
  - Storability vs. consumer demand?
  - Basically: all **mainstream cultivars** can be infected by postharvest rots.
  - Some cultivars: Gala, Honeycrisp, Fuji, Bosc (pear) **more prone to rots**
  - No source of resistance to postharvest pathogens in current cultivars
## Cultivar Susceptibility

<table>
<thead>
<tr>
<th>Cultivar</th>
<th>Blue mold</th>
<th>Gray mold</th>
<th>Bull’ eye rot</th>
<th>Mucor rot</th>
<th>Epidermis strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuji</td>
<td>5</td>
<td>3</td>
<td>2</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Braeburn</td>
<td>3</td>
<td>5</td>
<td>4</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>Golden Del</td>
<td>5</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Empire</td>
<td>4</td>
<td>6</td>
<td>5</td>
<td>5</td>
<td>-</td>
</tr>
<tr>
<td>Jonagold</td>
<td>5</td>
<td>4</td>
<td>6</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Royal Gala</td>
<td>2</td>
<td>3</td>
<td>6</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Granny Smith</td>
<td>3</td>
<td>3</td>
<td>4</td>
<td>6</td>
<td>6</td>
</tr>
</tbody>
</table>

- High variability between seasons

2: lowest susceptibility; 6: highest susceptibility

Spotts et al. 1999
Host resistance to postharvest diseases

- **Wild apple**: *Malus sierversii* (central Asia)
- Lines resistant to *Penicillium expansum* (Blue mold)
- Crosses are being made and tested for resistance and phenology (USDA-ARS-East Coast)

Wisniewski et al. 2011

Long term objective: ~6-8 years
### Mineral Nutrition

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Crop</th>
<th>Pathogen</th>
<th>Effect</th>
<th>Increase/Decrease ratio*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>Grape</td>
<td><em>Botrytis cinerea</em></td>
<td>Increase</td>
<td>1.0</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>0.5</td>
</tr>
<tr>
<td>Potassium</td>
<td>Apple, Cabbage, Grape</td>
<td><em>N. Malicorticis</em> (Bull’s eye rot) <em>Botrytis cinerea</em></td>
<td>Increase/Decrease</td>
<td>0.4</td>
</tr>
<tr>
<td>Calcium</td>
<td>Apple, Pear</td>
<td><em>Alternaria sp.</em> <em>Colletotrichum sp.</em> <em>Botrytis cinerea</em> <em>Phialophora (Side rot)</em></td>
<td>Decrease</td>
<td>-</td>
</tr>
<tr>
<td>Magnesium</td>
<td>Apple, Poppy</td>
<td>Replant disease <em>Alternaria, Cladosporium</em></td>
<td>None</td>
<td>0.8</td>
</tr>
<tr>
<td>Manganese</td>
<td>-</td>
<td>Several soil pathogens</td>
<td>Decrease</td>
<td>0.2</td>
</tr>
<tr>
<td>Zinc</td>
<td>-</td>
<td>Mycotoxin fungi: <em>Penicillium, Aspergillus</em></td>
<td>Decrease</td>
<td>0.1</td>
</tr>
<tr>
<td>Copper</td>
<td>-</td>
<td>Serval pathogens</td>
<td>Decrease</td>
<td>0.1</td>
</tr>
</tbody>
</table>

* Ratio between the number of studies reporting increased effect/decreased effect
Postharvest Diseases

The Pathogen

- Infection vs. Disease (pathogen)

- Fungi (most)  Bacteria (Fire blight, Bacterial canker)  Viruses

- How to manipulate the pathogen?
  - Exclusion: Certified plants (viruses, Phytophthora, Anthracnose, Nectria)
  - Reduce dispersion: Drip irrigation, mulch
  - Sanitation: preharvest (addressed) and postharvest
  - Apply the right biofungicides (if available) at the right time
Postharvest Diseases

Pathogen Management

- Pre-harvest sanitation
  - Orchard management

Disease

Pathogen
Postharvest Diseases

Pathogen Management

- **Pre-harvest sanitation**
  - **Pruning**: Manchurian crab apple trees

- **Sphaeropsis**
- **Phacidiopycnis**
- **Lambertella (Yellow rot)?**
Postharvest Diseases

Pathogen Management

- **Pre-harvest sanitation**
  - **Pruning**: crab apple trees

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**Incidence (%)**

- **Orchard Phacidio infection**
  - Unpruned: 15%
  - Chainsaw: 7%
  - Detailed: 2%

- **Speck rot in storage**
  - Unpruned: 12%
  - Chainsaw: 8%
  - Detailed: 3%

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Kim et al. 2016, WTRC reports
Postharvest Diseases

Pathogen Management

- Pre-harvest practices
  - Overhead irrigation: can increase moisture

[Diagram showing disease and pathogen management]
Pre-harvest sanitation

- Leaves: Source of Botrytis, Nectria
- Leaf removal or decomposition
- Sugar beet vinasse sprays
<table>
<thead>
<tr>
<th>Fungicide</th>
<th>Active ingredient</th>
<th>Target Disease</th>
<th>On the Label*</th>
<th>PHI</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Based on label recommendations</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Green</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GreenCure/Kaligreen/Bi-Carb</td>
<td>Bicarbonates</td>
<td>♦ Botrytis</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Copper products</td>
<td>Copper</td>
<td>♦ Anthracnose</td>
<td>♦</td>
<td>CL</td>
</tr>
<tr>
<td></td>
<td></td>
<td>♦ Nectria</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

+ On the label for pome fruit
- Not on pome fruit label but reported on other crops

WSU has not tested these products
Postharvest Diseases

Major problem for organic pome fruit

Production: 3x increase in 3-5 years

How to extend the shelf-life of larger volumes?
Postharvest Diseases

The Pathogen

Management in Postharvest

- Harvest fruit at commercial maturity
- Over-ripe fruit are more susceptible
Postharvest Diseases

The Pathogen

Management in Postharvest

- **Room and bin sanitation** is a key
  - *Penicillium* (Blue mold)
  - *Cladosporium* (Secondary pathogen)
  - Bacteria/yeasts

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Amiri et al. 2005
Postharvest Diseases

The Pathogen

Management in Postharvest

- Room and bin sanitation is a key
- Inoculum size at start is crucial

![Graph showing disease incidence over months of storage for different initial inoculum sizes, with Cultivar with high susceptibility and Cultivar with lower susceptibility labeled.]

Dutot et al. 2013.
Room and bin sanitation is a key management in postharvest.

Ozone fogged for 4-6 hours

Empty rooms

Postharvest Diseases

The Pathogen

Management in Postharvest

Amiri et al. 2016.
Physical control

- Hot air: used in orchards/vineyards
- Quarantine method: several insect pests

- Thermotherapy: Heat air/hot Water (45-48°C/113-118°F for 2-30 min)
  - Bull’s eye / Alternaria / Nectria rots
  - Gray mold (questionable)

- Large volume and Sustainable energy costs?
Postharvest Diseases

The Pathogen

Management in Postharvest

- **Biological and alternative methods**
  - Biological: inconsistent efficacy & wet application
  - May help for short-term storage

<table>
<thead>
<tr>
<th>Fungicide</th>
<th>Active agent</th>
<th>Agent type</th>
<th>Available in USA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bio-Save</td>
<td><em>Pseudomonas syringae</em></td>
<td>Bacteria</td>
<td>+</td>
</tr>
<tr>
<td>Boni Protect</td>
<td><em>Aureobasidium pullulans</em></td>
<td>Yeast</td>
<td>- (new in Europe)</td>
</tr>
<tr>
<td>Candifruit</td>
<td><em>Candida sake</em></td>
<td>Yeast</td>
<td>-</td>
</tr>
<tr>
<td>Nexy</td>
<td><em>Candida oleophila</em></td>
<td>Yeast</td>
<td>-</td>
</tr>
</tbody>
</table>

- **Natamycin (pimaricin):** From *Streptomyces natalensis*
- Natacyn drug to treat eye fungal infections
- Food preservation
- Pace: working on the development…
- Hope: sustainable mid/long term storage?
### Other postharvest alternatives

<table>
<thead>
<tr>
<th>Method</th>
<th>Benefits</th>
<th>Limitations</th>
<th>Commercial use</th>
</tr>
</thead>
<tbody>
<tr>
<td>UV-C</td>
<td>-Good sanitation</td>
<td>-Kills spores on surface</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td>-Induce host resistance</td>
<td>-Lack or harmonization</td>
<td></td>
</tr>
<tr>
<td>Chemical elicitors</td>
<td>-Enhance fruit resistance</td>
<td>-Wet application</td>
<td>+/?</td>
</tr>
<tr>
<td></td>
<td>-Natural products</td>
<td>-Unstable efficacy</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>-Not all allowed in organic</td>
<td></td>
</tr>
<tr>
<td>Ozone</td>
<td>-Gas or fog application</td>
<td>-Does not penetrate natural openings/wounds</td>
<td>+ (gas)</td>
</tr>
<tr>
<td></td>
<td>-Cost sustainable</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>-Additional applications during storage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulfur dioxide</td>
<td>-Good efficacy against postharvest decay</td>
<td>-Fruit injury risks</td>
<td>+</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-Sulphite residue</td>
<td></td>
</tr>
</tbody>
</table>
Thank you